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Injection molded plastics with aluminum foam core

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Abstract

Manufacturing route for parts which consist of aluminum foam core coated with polypropylene will be presented in this paper. For this purpose the complex 3-D shaped foam cores were manufactured. The cores were coated with polypropylene through the injection molding process. The polypropylene coating closes cracks in the foam core and improves mechanical properties of the part.

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Keywords: Aluminium foam, injection molding, surface treatment, bending test, deformation energy

1. Introduction

Lightweight sandwich structures have already been using and experimentally testing in wide range of applications with regard on manufacturing parameters (Hanssen (2002)), (Simone (1998)), (Deshpande (2000)), (Kanahashi (2000)). However, sandwich structures with aluminum foam core which are typically covered with metal surface sheet are less in use. The main cause is higher surface weight compared to other sandwich structures; i.e. honeycombs; and also the price. Panels or parts of aluminum foam made through the powder metallurgy route (Banhart (2001)) consist of porous structure completely covered with thin surface skin. The main drawback of the aluminum foam parts are cracks in the cell walls as well as on the surface skin. These cracks decrease mechanical

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properties of the part and cause problems during the coating. Therefore, new approaches for the improvement of the coating techniques are needed.

2. Experimental Approach

2.1. Preparation of Al-foam Samples

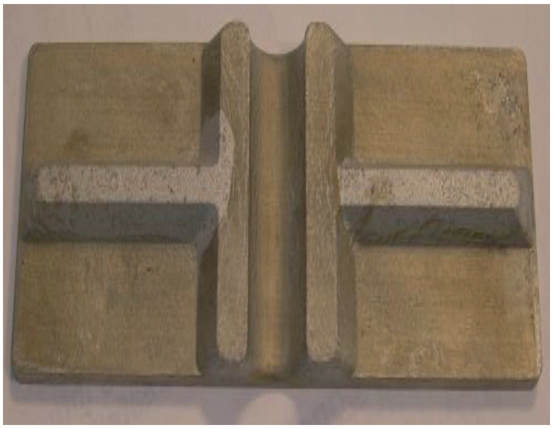

Figure 1: As-foamed sample.

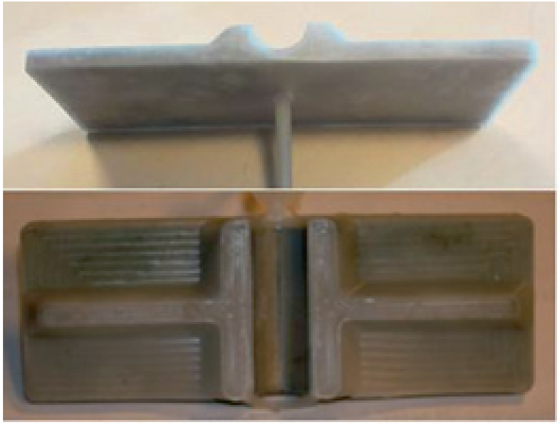

Figure 2: Foam sample after the injection of the polypropylene from the both sides.

Experiments were performed on 3-dimensional shaped Al-foam samples as shown in Fig.1 with dimensions width x thickness x length = 57x12x170mm and volume 69cm^3. Apparent density of the foam samples was about 1g/cm^3. Chemical composition of the foamable precursor was Al+10wt%Si+0,8 wt% TiH2. The precursor was manufactured by SAPA Profiles Slovakia. On Fig.2, there is presented sample after injection moulding.

2.2. Injection

The injection experiments were performed by ESOX-Plast Company on industrial injection press. Polypropylene 400-CA70 and also glass reinforced polypropylene (Boreallis PP GF 30) were used for these experiments. The injection mold was designed for two step injection cycle. Because of this, it was also possible to inject the polypropylene only on one side of the foam sample.

2.3. Surface treatment of foam sample

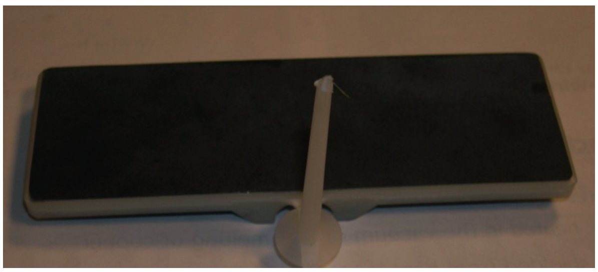

Figure 3: NiAl coated foam sample after the injection of the polypropylene on the back side of the sample.

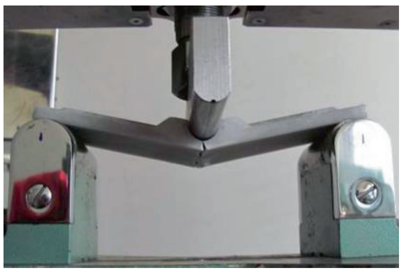

Figure 4: 3-point bending test on the polypropylene coated foam sample.

Foam samples were pre-coated prior to the injection process with NiAl powder using flame gun deposition technique. The pre-coating closed the cracks on the surface and thus avoided penetration of polypropylene into the porous structure (Fig.3).

2.4. 3-point Bending

Bending experiments were performed on the foam samples with polypropylene injected only on one side (Fig.4). For the reference a sample made only of the polypropylene was taken. The experiments were performed on instrumented test device with 100 KN maximal loading capacity. Distance between the supports was 150 mm. The samples were loaded at weakest cross section (Fig.5). 3-point bending profiles were recorded during the experiments. Absorbed deformation energy was calculated as a surface below the force-displacement curve. Bending stiffness was evaluated through the regression trendline at quasi-elastic region of the bending profile.

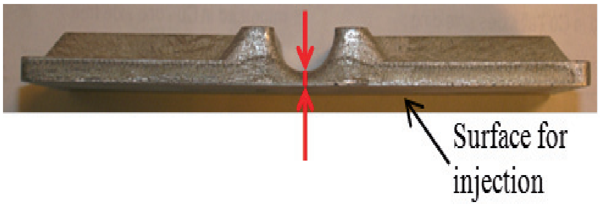

Figure 5: Aluminum foam sample. Weakest cross-section in the middle of the sample is marked by the arrows.

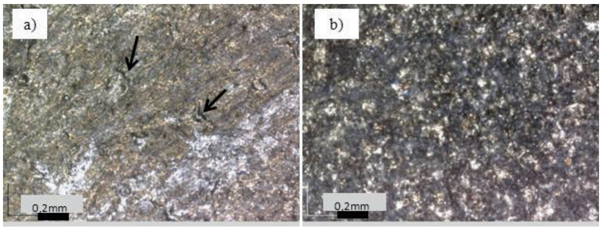

Figure 6: Detailed view on the surface of foam sample: a) Without pre-coating – surface cracks are marked by arrows, b) With pre-coating – surface cracks are covered by the coating

3. Results and Discussion

As can be seen in Fig 6a, surface of foam sample contains plenty of small cracks which cause the penetration of liquids into the pores. These cracks were created during the solidification of the foam. It is no possible to avoid the creation of these cracks. Therefore, the pre-coating with NiAl powder was used (Fig.6b).

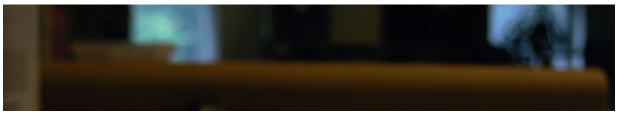

Figure 7: Effect of the pre-coating of the surface of the foam sample. Left – with the pre-coating – no penetration of the polypropylene was observed. Right – without pre-coating – penetrated polypropylene in the porous structure.

Figure 8: Detailed view on the cross-section foam sample-polypropylene.

Effect of the pre-coating is presented in Fig.7. There was observed no penetration of the polypropylene into the porous structure in case of the pre-coated foam samples (Fig.8).

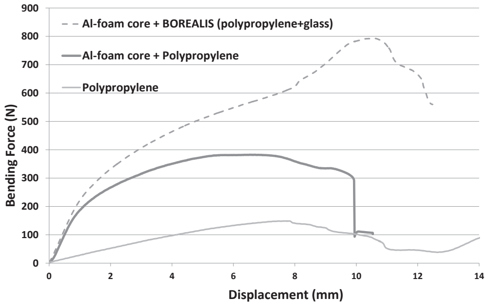

Figure 9: Bending force vs. deformation profiles.

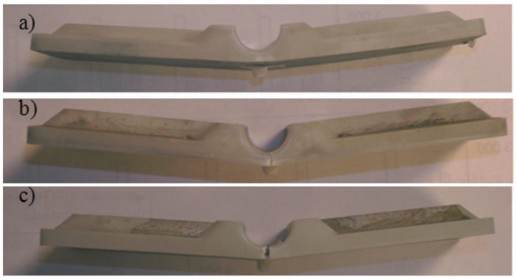

Figure 10: Samples after the 3-point bending test: a) Polypropylene, b) Foam sample with polypropylene coating. c) Foam sample with glass fiber reinforced polypropylene coating.

The 3-point bending experiments showed difference in bending stiffness and strength between the reference polypropylene sample and the polypropylene coated foam samples. As it is presented in Fig. 9 foam sample with polypropylene coating reached significantly higher strength and stiffness at similar weight compared to the reference polypropylene sample. Foam sample coated with the stronger glass fiber reinforced polypropylene reached highest bending strength.

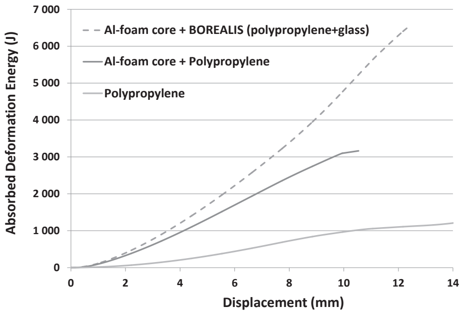

Figure 11: Absorbed deformation energy vs. deformation profiles.

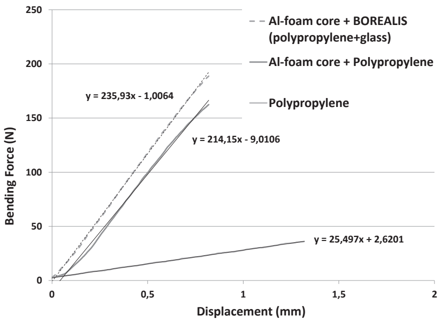

Figure 12: Quasi-elastic part of the bending force vs. displacement profiles with regression trendlines for the bending stiffness comparison.

Deformation energy absorption vs. displacement profiles are presented in Fig. 11. Amount of absorbed deformation energy corresponds with the bending profiles. Largest amount of the deformation energy was absorbed by the foam sample coated with glass fiber reinforced polypropylene.

Table 1. Summary of mechanical properties.

SAMPLE	WEIGHT	MAXIMAL BENDING STRENGTH (N)	ABSORBED DEFORMATION ENERGY (J)
Reference polypropylene	65	148	1266,00
Al-foam + polypropylene	75	382	3164,50
Al-foam + glass reinforced polypropylene	76	792	9036,78

Differences in bending stiffness between the samples can be seen in Fig. 12. Contribution of the aluminum foam to the stiffness was significant in this case. Measured and calculated values and parameters are summarized in table I.

4. Conclusion

Because of the nature of aluminum foam it is required to cover the surface cracks prior to the injection molding process. Mechanical properties of the coating material are very important for the bending strength and ductility of the final part with aluminum foam core. Bending stiffness depends mostly on the stiffness of the aluminum foam core.

Acknowledgements

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